

Time-Based and Latitudinal Assessment of Contaminated and Clean Water Quality on Concrete Strength

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Abstract- With increasing population and demand for infrastructural development in many developing countries, the demand for concrete has been on the increase and does not show any sign of slowing down in the nearest future. Existing concrete structures are also deteriorating and require repair or replacement. In this study, multivariate methods of factor analysis (FA) and cluster analysis (CA), were applied to analyze the liquefied samples datasets for clean and contaminated (sewage) water obtained in Ado- Odo Ota, Ogun State, Nigeria. FA clearly identified two groups of liquefied samples and indicated that the bacterial parameters are higher in fermented locust beans water which can be likened to presence of *bacillus subtilis* food type. Hierarchical cluster grouped 40 samples into two which are high and low levels of bacteria contents respectively. Descriptive statistics showed all parameters significantly (conductivity, TDS, BOD, COD, carbondioxide, Calcium, Chlorine, pH, Temperature, salinity) in Cluster A greater than in cluster B. The main self- healing parameter for crack sealing up, because when bacteria commence feeding on calcium lactate once activated, oxygen consumed as the bacteria feeds and insoluble limestone formed by conversion of the soluble calcium lactate is greater for contaminated water against portable water values. This study demonstrates the usefulness of multivariate statistical techniques for evaluation of presence of bacteria in liquefied samples before used as self-healing.

Keywords— Carbondioxide, clean, self-healing concrete, water

1 INTRODUCTION

Concrete principal material in the building industry is a versatile material no matter how one tweak it, certainly at some point cracks will occur and main factors that gradually break the concrete are stress and weather conditions (Roig et al., 2015). Cracking is one of the key factors generating concrete durability degradation, timely repairs or self-healing for cracks prolong the service-life of concrete structures (Wang et.al., 2014a). Certainly, cracks repair is possible, but time consuming and expensive, mostly when the structure has to be closed down while the rehabilitation takes place (Qian et al., 2016). Thus, inspection and maintenance methods for concrete structures become the centre of interesting attention as traditional repair methods such as cement grouting and maintenance prove more difficult and expensive, with such context self-healing cracks in concrete ability raised wide spread attention (Hung & Damidot, 2013).

Self-healing of concrete has been reported to be mostly influenced by precipitation of calcium carbonate. Many researchers (Qian et al. 2016; Roig et al., 2015; Wang et al. 2014b and Ivanov, 2008) found that some bacteria could induce or improve the precipitation of CaCO_3 . This phenomenon which was called bio-mineralization existed widespread in nature. Self - healing concrete is the concrete that cures itself when senses its crack formation without human intervention, that is product that mend cracks that emerge on the surface of concrete structures by producing limestone biologically. It is concrete that holds self-healing agents, which will automatically heal" concrete structures, when there is occurrence of cracks throughout their life cycle. Self-healing agents may be moved through forms of organic matter, strong core microcapsules and by hollow reinforced fibers and they can lie dormant inside the concrete for up to 200 years (Dong, 2015; Dhami et al., 2013).

Though, when a concrete structure is ruined and water starts to leak through the cracks that emerge in the concrete, contact with the nutrients and water causes bacteria to germinate. Bacteria commence feeding on calcium lactate once activated, oxygen consumed as the bacteria feeds and insoluble limestone formed by conversion of the soluble calcium lactate. Sealing up occur as cracked surface solidifies by limestone. It imitates the technique by which bone breaks in the human body are normally healed by osteoblast cells that mineralise to rectify the bone. Oxygen consumption throughout the bacterial transformation of calcium lactate to limestone is an additional advantage. Oxygen is a vital element in the corrosion of steel method and when the bacterial activity has ingested it all steel reinforced concrete construction durability rises.

Fermented locust beans (*Parkia biglobosa*) are one of the accepted food condiments in West and Central Africa regions. This nutritious and delicious food spice is commonly referred to as "iru" in Yoruba, "bindo" in Bassa, "ogiri" in Igbo, or "dadawa" in Hausa languages in Nigeria. It is used as food flavor and nutritional value enhancement in Nigeria, Ghana, Sierra Leone and Togo. The fermented locust beans can introduce bacteria into concrete and induce self-healing of the concrete.

Multivariate analysis, like multidimensional scaling and cluster analysis, can utilize input of the raw data which assimilate the original quality and output results which can be more precise than when multiple computations of estimate summaries of descriptive and inferential statistics are used as standalone, with an inductive logic to deduce relationships in the datasets. Principle component analysis reduces the data into a few significant components (Luo et al., 2017) while factor analysis explores the intrinsic quality and relationships in the few principal components.

This research work hypothesizes that some of the substances that can induce self-healing of concrete may also affect the strength properties of the concrete.

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Consequently, this research work investigated the effects the use of each of fermented locust beans and portable (as mixing fluid while producing concrete) has on the strength of the concrete.

2 MATERIAL AND METHODS

2.1 MATERIALS

Samples of fermented locust beans and Potable water, having a pH value of 7.0 was taken before used for the mixing and curing of the concrete specimens that served as control specimens. In preparing the fermented locust beans, locust beans seeds were soaked in water and were boiled for seven hours to soften the seed coat and the cotyledon. The boiled seeds were afterwards transferred into a basket lined with banana leaves to prevent heat loss and left to ferment for 72 hours. They were then mashed in the soaked water using mortar and pestle besides digest the content to liquid form. The sewage were collected from Ota waste water collection place in Ado Odo, Ota local government in Nigeria, the samples weighed 50 litres.

2.2 METHODS

Ten (10) consistently sampled parameters were selected. The parameters are pH, Temperature, Electrical Conductivity, Salinity, Turbidity, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Chlorine, Carbondioxide, Calcium (Ca). Contaminated and clean water samples were collected for each of these parameters using plastic containers, stored in a cooler at 4°C and transported to the laboratory for analysis within 6 hours. In situ analyses were performed on five parameters: pH, temperature, Electrical conductivity, salinity and TDS while the remaining five parameters were analysis in the laboratory based on APHA, (1988) standards.

2.3 DATA TREATMENT AND STATISTICAL ANALYSIS

Factor analysis (FA) that has the capacity of reducing variables number and categorizes latent information in datasets was engaged, so as to distinguish the factors affecting the quality of liquefied samples in the self-healing concrete. Before FA carried out, the data was scrutinized for appropriateness using the Kaiser-Mayer-Olkin (KMO) test which give 0.918 (>0.5) and Bartlett's sphericity ($p < 0.000$), test. KMO and Bartlett's sphericity test result reveal that FA is suitable for the liquefied quality data in this study. An insignificant latent factors numbers with a matrix of factor loadings or Varifactors (VFs) were produced during factor analysis process and factors with an eigenvalue ≥ 1 were included in this research. To end with, varimax-rotated as the factor loading matrix was employed in order to minimize the impact of certain variables with a lesser amount of significance and increase the impact of variables having greater significance (Dung et al. 2015).

Hierarchical Cluster analysis (HCA), the most prevalent techniques was employed to sigh-see the spatial patterns of liquefied sample quality in the self-healing concrete. The objects are classified by relating inter-sample unities in a manner that the outcome validates the broad similarity of the components in a given set of data (Luo

et al., 2017; Razmkhah et al. 2010). Clusters begins with two of the most related objects and developing advanced clusters in a stepwise manner with dendrogram as the output, while the similarities and variations are computed through Euclidean distance measurement. Ward's system of hierarchical agglomerative cluster analysis was engaged to ascertain the multivariate likeness amongst different liquefied samples. One-way ANOVA was then applied to ratify the groups identified through scrutinizing their significant spatial differences ($p < 0.05$) besides to avert misclassification instigated by broad disparities in data dimensionality (Luo et al., 2017). To systematize liquefied samples quality, Z-scale transformation was applied (except pH) prior to analysis (Al-murairi et al. 2014; Singh et al. 2004). IBM SPSS 20.0 software was engaged for treating data and multivariate statistical analysis.

3 RESULTS AND DISCUSSION

3.1 DESCRIPTIVE STATISTICS

The descriptive statistics values of the concrete produced using the two categories of mixing liquefied are presented in table 1 and graphically represented in Figure 1-3.

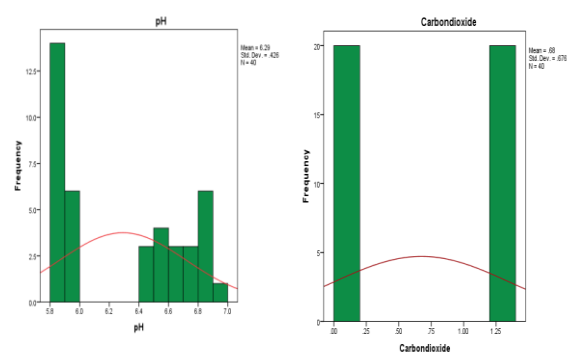


Fig. 1: Descriptive statistics values of the concrete produced using the two categories of water: pH and Carbondioxide

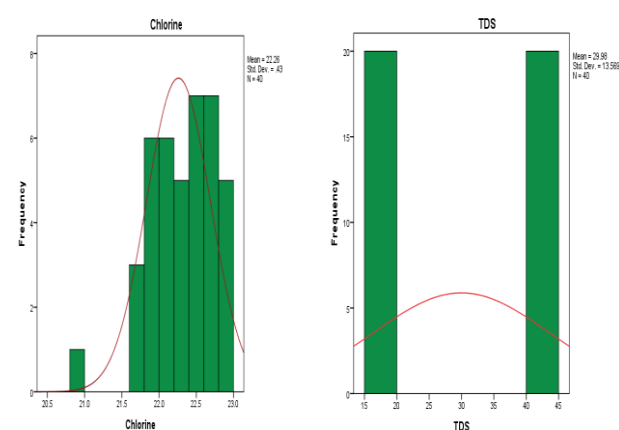


Fig. 2: Descriptive statistics values of the concrete produced using the two categories of water: Chloride and TDS.

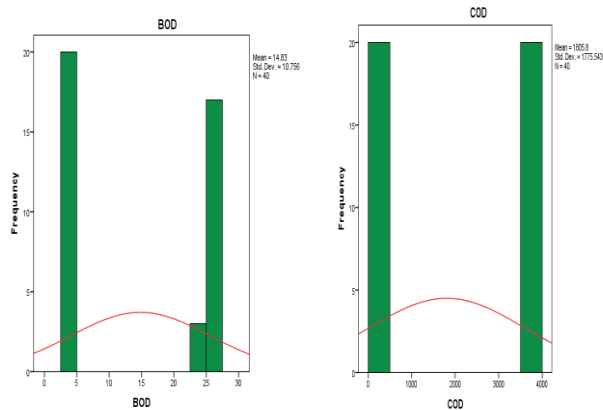


Fig. 3: Descriptive statistics values of the concrete produced using the two categories of water: BOD and COD.

The result showed that COD has the highest mean (1805.80mg/l) and followed by Conductivity (52.60 μ S/cm) while Carbondioxide recorded the lowest (0.68ppm). Also, COD recorded the highest Standard deviation (1775.54mg/l). This was followed by Conductivity (28.936 μ S/cm) while Temperature recorded the least value of (0.384mg/l).

Table 1. Descriptive Statistics Result

Parameter	Mean	Min	Max	SD	Variance	Skewness	Kurtosis
Cond	52.60	23.00	82.00	28.94	837.28	-0.00	-2.10
pH	6.29	6.00	7.00	0.43	0.18	0.16	-1.86
Temp	28.56	28.00	30.00	0.38	0.15	-0.00	0.83
Sal	31.13	21.00	41.00	9.90	97.96	-0.00	0.73
CO ₂	0.68	0.00	1.00	0.68	0.46	-0.00	-2.11
Cl	22.26	21.00	23.00	0.43	0.19	-0.75	0.89
Ca	11.36	4.00	19.00	6.84	46.83	0.00	-2.10
TDS	29.98	16.00	44.00	13.59	184.12	-0.00	-2.11
BOD	14.83	4.00	26.00	10.76	115.69	0.00	-2.10
COD	1805.80	50.00	3585.00	1775.54	3152553.76	0.37	0.73

3.2 KMO AND BARTLETT'S TEST

To examine the suitability of these data for principal component analysis/factor analysis, Kaiser-Meyer- Olkin (KMO) and Bartlett's tests were performed. KMO is a measure of sampling adequacy that indicates the proportion of variance. The KMO and Bartlett's Test of the concrete produced using the two categories of mixing liquefied are presented in table 2.

Table 2. KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of sampling Adequacy	Bartlett's Test of Sphericity		
	Approx. Chi Square	df	Sig.
0.918	1637.577	45	0.000

Result from Table 2- 3 compare the compositional patterns between the examined water systems and identify the factors that influence each one. Three principal components were obtained with eigenvalues >1

summing 100% of the total variance in the water dataset also with significance < 0.05.

Table 3. Water quality parameter grouping based on PCA

VF _{s1}	VF _{s2}	VF _{s3}
pH	BOD	Salinity
Temperature	COD	Calcium
TDS		Conductivity
Chloride		Carbondioxide

Factor analysis yielded three variance factors (VFs) with eigenvalues ≥ 1 , explained 93.570 of the total variance in the data set, respectively. Factor analysis results including the loadings, variance contribution rate of each variance factor (VF), and cumulative variance contribution rate are presented in Table 4 and graphically represented in Figure 4.

Table 4. Parameter and variance factor

Parameter	VF _{s1}	VF _{s2}	VF _{s3}
Conductivity	765.45	836.18	837.28
pH	0.18	0.17	0.012
Temperature	0.15	0.011	0.012
Salinity	92.45	97.80	97.96
Carbondioxide	0.045	0.45	0.46
Chloride	0.19	0.006	0.002
Calcium	34.23	46.80	46.83
TDS	184.12	184.02	172.23
BOD	56.46	115.57	45.35
COD	245567.45	3152553.76	256789.78
% of variance	92.56	96.43	100.00
Cumulative % variance	92.56	96.43	100.00

Among the three VFs, VF_{s1} explained that 92.56 % of total variance had strong loading on Chloride, moderate positive loading on TDS and temperature, strong negative loading on pH. VF_{s1} represented microbial factor pollution sources such as municipal and industrial effluents pollution, leachates of salts pollution from the nearby dumpsite in the area and agricultural activities, sewage disposal etc. VF_{s2} explained 96.427 % of the total variance and had strong loading BOD and COD. VF_{s2} represented mixed pollution factors: natural and organic pollution. These specific elements seem to be tracked back to sampling stations 3 and 4. EC is an index of natural pollution. While VF_{s3} explained 100.0 % of the total variance and had strong positive loading on conductivity, carbondioxide, calcium and salinity.

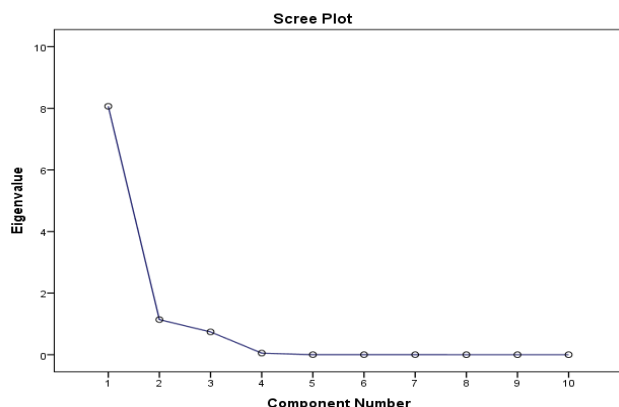


Fig. 4: Screen Plot of the concrete produced using the two categories of mixing liquefied.

3.4 CLUSTER ANALYSIS (USING SQUARED EUCLIDEAN DISTANCE)

The cluster analysis of the concrete produced using the two categories of mixing liquefied are presented in table 6 and graphically represented in Figure 5. Result from figure 5 detect similarity groups between the liquefied samples. Two statistically significant clusters are formed Cluster 1 and Cluster 2, which yielded two groups of similarity between the water samples, i.e., contaminated water as high impact and clean water as moderate impact on the concrete produced. Temporal cluster analysis was used on standardized log-transformed data sorted by liquefied. CA was performed using squared Euclidean distances as a measure of similarity. Based on the 10 variables, CA classified the four sampling stations into two distinct clusters: clusters A and B. Cluster A was formed by stations 3 and 4 while stations 1 and 2 were ascribed to cluster B. Temporal CA generated a dendrogram as shown in Fig. 6. Group A consisted sample 21 -40 representing contaminated beans water and the cluster B consisted of sample 1 - 20 which is clean water. The temporal patterns to water quality were consistent with the two samples.

Furthermore, an internal analysis of cluster A showed that sampling stations 3 and 4 had similar features also Cluster B, stations 1 and 2 were grouped with similar characteristics. The water quality differences in the clusters reflected difference in basin origins and morphology as well as showed that there were two different liquefied water qualities in the concrete casted. The CA technique reduced the need for numerous sampling stations besides exhibited that the CA technique was useful in classification of self-healing liquefied water samples.

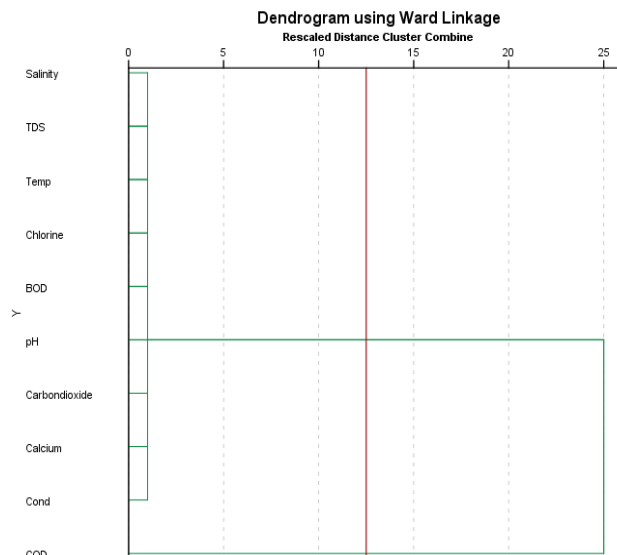


Fig. 5: Dedrogram using ward linkage of the concrete produced using the two categories of mixing liquefied.

3.5 TEMPORAL SIMILARITY AND VARIATIONS OF LIQUEFIED WATER SAMPLES

The temporal variation of liquefied water samples was determined, contaminated water produced concrete that increase in compressive strength, split tensile strength and flexural test. Which also reflect in the physiochemical parameters of liquefied sample test before casting of concrete. For temperature, clean water (27.9– 29.5 °C) and contaminated (Sewage) water (28.1– 28.7 °C) values is nearly the same. For TDS, high values were observed in contaminated water (43.0 – 43.7ppm) and low values in portable water (15.9 – 17.20ppm).

For salinity, high values were observed in contaminated water (40.6 – 41.4 ppm) and low values in clean water (20.7 – 22.5 ppm). For conductivity, high values were observed in contaminated water (81.0 – 81.3mg/L) and low values in clean water (22.9 -28.7mg/L). For carbondioxide, high values were observed in contaminated water (1.31 – 1.38 ppm) and low values in clean water (0 – 0.02 ppm). For Ca, high values were observed in contaminated water (17.7 – 18.5mg/L) and low values in clean water (4.4 – 4.78 mg/L). For BOD, high values were observed in contaminated water (3.8- 4.43 mg/L) and low values in clean water (6.8- 7.6 mg/L).

The BOD mean concentration for contaminated water was higher than clean water, suggesting a present of bacteria that can heal the cracks. For COD, high values were observed in contaminated water (3551- 3562 mg/L) and low values in clean water (49.5 – 58.2 mg/L). For chloride, high values were observed in contaminated water (22.0 – 22.8 mg/L) and low values in clean water (21.6 – 22.9 mg/L). The water pH values were higher in clean water compared to those of contaminated water. The variation of water physiochemical parameters showed a clear-cut bacteria effect.

4 CONCLUSION

This study used various multivariate statistical techniques to evaluate two liquefied samples. Multivariate methods, such as factor analysis (FA) and cluster analysis (CA), were applied to analyze the liquefied samples datasets for clean and contaminated water obtain in Ado- Odo Ota, Ogun State, Nigeria. FA clearly identified two groups of liquefied samples and indicated that the bacterial parameters are higher in fermented locust beans water which can be liken to present of bacillus subtilis food type. Hierarchical cluster grouped 40 samples into two clusters, which is high and low level of bacteria content respectively.

Descriptive statistics exhibited all parameter significantly (conductivity, TDS, BOD, COD, carbondioxide, Calcium, Chlorine, pH, Temperature, salinity) in Cluster B less than in cluster A. The main self- healing parameter for crack sealing up, because when bacteria commence feeding on calcium lactate once activated, oxygen consumed as the bacteria feeds and insoluble limestone formed by conversion of the soluble calcium lactate is greater for contaminated water than clean water. The contaminated water values may be attributed to the activities of bacteria fermented locust beans leading to the formation of calcium carbonate in the concrete. It can be concluded that the use of baccilus subtilus from fermented locust and contaminated water as mixing fluid during the casting of concrete samples to induce self-healing will led to increased strengths (compressive, flexural and split), which is in agreement with research work made by (Arthi & Dhaarani, 2016) and (Manikandan & Padmavathi, 2015).

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